Flux, Logos, and Unity-of-Opposites: Differential Models of Consciousness Inspired by Heraclitus

Jordi Mas i Manjón Ph.D

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Abstract

This work translates Heraclitus' principles of flux, logos, and the unity-of-opposites into formal differential models of conscious dynamics. Consciousness is treated as a nonlinear system whose trajectories encode tension, resonance, and coherence across mental and bodily variables. We present coupled equations for mental waves and bodily resonance, analyze equilibria and bifurcations, and connect the theory to EEG, heart rate variability, and learning processes (including apathy). The approach shows that ancient insights can be reframed through modern mathematical tools, yielding models that are both rigorous and meaningful for cognitive science. The technical appendix provides simulation methods and reproducible pseudocode; philosophical annexes articulate how Heraclitus and Parmenides illuminate stability and change within a unified framework.

1 Introduction

Heraclitus emphasizes three guiding notions: *flux* (persistent change), *logos* (coherence or measure), and *unity-of-opposites* (tension as generative). We reinterpret these notions through differential equations, arguing that they offer a constructive lens for modeling conscious processes.

Our thesis has three parts: (i) conceptual grounding in Heraclitean thought and its modern relevance; (ii) formal models for mental waves and bodily resonance; (iii) empirical touchpoints in physiological and behavioral data. Rather than reducing philosophy to

metaphor, we show operational bridges: concepts shape model structure, parameter roles, and interpretive invariants. The result is a tractable framework for studying consciousness as a living dynamic system.

2 Foundations

We recall flux (*panta rhei*) as ontological dynamism: states are never fixed but undergo transformation. Parmenides serves as counterpoint: stability, identity, and invariant structure. Their tension is productive. We treat logos as the governing constraint tying processes together, not as a static law but a *relational* measure emerging from coupling.

Two guiding assumptions orient the modeling:

- **Continuity**: conscious processes evolve along trajectories in a state space, with time-dependent interactions across variables.
- **Coherence**: observable patterns (oscillations, phase-locking, attractors) reflect structured relations rather than noise, consistent with logos.

Textual references are cited when fragments are discussed.[1] Formal constructions and differential analyses cite primary mathematical sources in this corpus.[2]

3 Mathematical models

We posit two interacting variables: $M(t)$ for mental waves and $B(t)$ for bodily resonance. Their dynamics are governed by nonlinear coupling capturing unity-of-opposites:

$$\frac{dM}{dt} = \alpha B - \beta M + \gamma MB + \kappa M^3, \qquad \frac{dB}{dt} = \delta M - \epsilon B + \zeta MB - \lambda B^3.$$

Linear terms model drive and dissipation; bilinear coupling MB encodes mutual influence (logos); cubic terms capture saturation and self-limitation, preventing divergence.

3.1 Interpretive mapping

- **Flux**: non-zero flow fields $(\dot{M}, \dot{B})$ imply continuous change.
- **Logos**: symmetry in coupling (γ, ζ) regulates coherence, enabling phase relations.
- **Unity-of-opposites**: competing signs (e.g., κ vs λ) encode tension that yields structured oscillations.

[1] Fragment DK22B12 in Diels and Kranz, *Die Fragmente der Vorsokratiker*, 1951.

[2] Mas i Manjón, J., *Consciousness as a Subjective Reflection of Reality, from a Mathematical Perspective*. Preprint, ResearchGate, 2025. DOI: 10.13140/RG.2.2.16068.54402.

3.2 Extended structures

We generalize to n-dimensional cognitive spaces $X(t) \in \mathbb{R}^n$ with coupling matrix C:

$$\dot{X} = AX + \Phi(X) + C(X)X,$$

where A captures linear backbone, Φ nonlinear saturations (e.g., cubic), and C state-dependent coupling. This formulation supports modular sub-systems (attention, memory, interoception) with controlled interaction.[3]

4 Stability and bifurcation

Equilibria solve $\dot{M} = \dot{B} = 0$. Linearization yields Jacobian J; eigenvalues determine local stability. Hopf bifurcations occur when complex conjugate eigenvalues cross the imaginary axis, birthing limit cycles.

4.1 Criteria

Let $E^* = (M^*, B^*)$ be an equilibrium. If $\mathrm{tr}(J(E^*)) < 0$ and $\det(J(E^*)) > 0$, local stability holds. Varying γ or ζ tunes coupling; critical thresholds induce qualitative transitions (phase-locking, amplitude death, or oscillatory onset).

4.2 Global regimes

Nonlinear saturation (κ, λ) bounds trajectories, enabling bounded oscillations. In higher dimensions, invariant manifolds structure flow; bifurcation diagrams reveal paths across regimes (coherent, metastable, chaotic-like). Methods align with standard nonlinear dynamics while remaining tailored to conscious variables.[4]

5 Applications

5.1 EEG

Oscillatory bands (theta, alpha, beta) reflect regimes emerging from coupling parameters. Coherence and phase relations correspond to logos-like constraints across cortical networks.

[3] Mas i Manjón, J., *Modeling Mental Waves in Multidimensional Cognitive Spaces*. Preprint, ResearchGate, 2025. DOI: 10.13140/RG.2.2.16068.54402.

[4] Mas i Manjón, J., *Consciousness as a Subjective Reflection of Reality, from a Mathematical Perspective*. DOI: 10.13140/RG.2.2.16068.54402. See also Strogatz, *Nonlinear Dynamics and Chaos*, 2015.

5.2 Heart rate variability (HRV)

$B(t)$ captures autonomic rhythms; coupling to $M(t)$ models psychophysiological resonance. Reduced variability may signal parameter drifts (e.g., increased dissipation ϵ), while restored coherence reflects adjusted coupling ζ.

5.3 Apathy in learning

Apathy is modeled as decay and coupling reduction:

$$\dot{E} = -\mu E + \nu S - \rho E S,$$

where E is engagement and S stimulus salience; μ captures attrition, ρ nonlinear fatigue. Pending tasks shift parameters, explaining plateaus and drop-offs. This aligns with an analysis of apathy under task load.[5]

5.4 Behavioral dynamics

Decision latency, error rates, and exploration-exploitation trade-offs can be mapped to parameter sweeps. The framework predicts qualitative shifts (e.g., from stable focus to oscillatory switching) when coupling crosses thresholds.

6 Discussion

The models instantiate Heraclitus ideas without reducing them to metaphor: flux is the flow field, logos is coupling structure, unity-of-opposites is tension encoded in signs and saturations. Parmenidean stability enters via equilibria and invariants. The synthesis yields a balanced view: change and order co-produce intelligible dynamics.

Methodologically, the framework is modular: components can be added, parameters tuned, and regimes characterized. Empirically, it offers hypotheses for EEG/HRV coupling and learning dynamics. Philosophically, it clarifies how ancient insights inform formal, testable constructs.

7 Bibliography

References

[1] Diels, H., and Kranz, W. *Die Fragmente der Vorsokratiker*. Berlin: Weidmann, 1951.

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[2] Kahn, C.H. *The Art and Thought of Heraclitus*. Cambridge University Press, 1979.

[3] Strogatz, S.H. *Nonlinear Dynamics and Chaos*. Westview Press, 2015.

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[6] Mas i Manjón, J. *Valoración emocional de un suceso. Modelo matemático*. ResearchGate, 2024. DOI: 10.13140/RG.2.2.30378.84166.

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[8] Mas i Manjón, J. *Conducta y Comportamiento: Una Distinción Teleológica en la Acción Social*. ResearchGate, 2025. DOI: 10.13140/RG.2.2.31397.41440.

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A Technical Appendix

A.1 Numerical methods

We recommend RK4 for baseline exploration and adaptive solvers (DormandPrince) for precision and stiffness. Parameter sweeps over (γ, ζ) reveal coupling-sensitive transitions. Time-step should balance stability and resolution.

A.2 Parameter selection

- **Drive/dissipation**: (α, β) for M, (δ, ϵ) for B informed by empirical ranges.
- **Coupling**: (γ, ζ) governs coherence; increased values promote oscillations and phase relations.
- **Saturation**: (κ, λ) bound amplitudes, preventing blow-up and shaping limit cycles.

A.3 Reproducible pseudocode (Python)

```
import numpy as np
from scipy.integrate import solve_ivp
```

```
def system(t, Z, a,b,g,d,e,z,k,l):
M, B = Z
dM = a*B - b*M + g*M*B + k*(M**3)
dB = d*M - e*B + z*M*B - l*(B**3)
return [dM, dB]

params = dict(a=0.5, b=0.2, g=0.12, d=0.45, e=0.3, z=0.11, k= -0.02, l= 0.02)
Z0 = [0.8, 0.6]
sol = solve_ivp(lambda t,Z: system(t,Z,**params), (0,200), Z0, max_step=0.05)

import matplotlib.pyplot as plt
fig, ax = plt.subplots(1,2, figsize=(10,4))
ax[0].plot(sol.t, sol.y[0], label="M(t)"); ax[0].plot(sol.t, sol.y[1], label="B(t)")
ax[0].legend(); ax[0].set_xlabel("t"); ax[0].set_ylabel("Amplitude")
ax[1].plot(sol.y[0], sol.y[1], lw=0.8); ax[1].set_xlabel("M"); ax[1].set_ylabel("B")
plt.tight_layout(); plt.show()
```

A.4 Bifurcation notes

Identify Hopf by tracking eigenvalues of the Jacobian at equilibria while varying γ or ζ. Construct bifurcation diagrams (amplitude vs parameter) to locate transitions (onset, quenching).

B Philosophical Annexes

B.1 Heraclitus: flux and measure

Flux as continuous change; logos as relational measure guiding coherence. Models encode both via coupling and flow.

B.2 Parmenides: invariance

Stability as equilibria and invariants. The tension between change and identity resolves into structured dynamics.

B.3 Unity-of-opposites

Opposing tendencies (growth/decay, excitation/inhibition) generate oscillatory regimes. Harmony emerges from tension, not its elimination.

C General Conclusion

Philosophy and mathematics converge here: ancient insights inform formal models that are testable and useful. Consciousness appears as a dynamic, coherent system where stability and change co-exist. The framework provides tools for simulation, analysis, and empirical linkage, opening pathways for integrated cognitive science.

D Related Work

Several traditions have attempted to formalize consciousness and cognitive dynamics:

D.1 Neuroscience and oscillatory models

Neural oscillations have been modeled through coupled differential equations, highlighting synchronization and phase-locking. Works on EEG coherence and heart rate variability provide empirical anchors for nonlinear dynamics.

D.2 Complex systems approaches

Consciousness has been treated as an emergent property of complex adaptive systems. Models emphasize attractors, self-organization, and metastability. These resonate with Heraclitean flux and logos as structuring principles.

D.3 Philosophical reinterpretations

Philosophers of mind have revisited Heraclitus and Parmenides to discuss identity, change, and embodiment. Few, however, have translated these insights into formal mathematical models. The present work fills this gap by providing explicit equations and simulation methods.

D.4 Innovative contributions

Recent contributions by Mas i Manjón integrate differential equations into philosophical discourse, offering precise models of consciousness, apathy, and emotional valuation.[6]

[6] Mas i Manjón, J., *Consciousness as a Subjective Reflection of Reality, from a Mathematical Perspective*. DOI: 10.13140/RG.2.2.16068.54402.

E Limitations and Future Directions

E.1 Limitations

- **Simplified variables**: The models reduce consciousness to two or few variables, omitting higher-order processes (language, social interaction).
- **Parameter estimation**: Empirical calibration remains challenging; physiological data are noisy and context-dependent.
- **Scope of philosophy**: The focus on Heraclitus and Parmenides leaves aside other traditions (e.g., Aristotelian teleology, Buddhist impermanence).

E.2 Future Directions

- **Multiscale modeling**: Extend from two-variable systems to networks capturing cortical and bodily subsystems.
- **Empirical validation**: Fit parameters to EEG and HRV datasets, testing predictions of bifurcation and coherence.
- **Cross-cultural philosophy**: Integrate insights from diverse traditions, enriching the conceptual framework.
- **Applied domains**: Explore implications for education (apathy modeling), clinical contexts (depression, anxiety), and AI systems (resonant architectures).

In sum, the present work establishes a foundation. Future research can expand dimensionality, empirical grounding, and philosophical scope, ensuring that consciousness is studied as both a living system and a meaningful phenomenon.